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15-METER ANTENNA PERFORMANCE OPTIMIZATION USING AN INTERDISCIPLINARY APPROACH

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ABSTRACT

A 15-meter diameter deployable antenna has been built and is being used as an experimental test system with which to develop interdisciplinary controls, structures, and electromagnetics technology for large space antennas. The program objective is to study interdisciplinary issues important in optimizing large space antenna performance for a variety of potential users.

The 15-meter antenna utilizes a hoop column structural concept with a gold-plated molybdenum mesh reflector. One feature of the design is the use of adjustable control cables to improve the paraboloid reflector shape. Manual adjustment of the cords after initial deployment improved surface smoothness relative to the build accuracy from 0.140 inches RMS to 0.070 inches.

Experiments have been completed in which preliminary structural dynamics tests and near-field electromagnetic tests were made. The antenna is now being modified for further testing. Modifications include addition of a precise motorized control cord adjustment system to make the reflector surface smoother and an adaptive feed for electronic compensation of reflector surface distortions. Although the previous test results show good agreement between calculated and measured values, additional work is needed to study modelling limits for each discipline, evaluate the potential of adaptive feed compensation, and study closed-loop control performance in a dynamic environment.

INTRODUCTION

The development of large, self-deployable antennas has been a major technology thrust for NASA during the past two decades. The need for

larger aperture antennas evolved from the requirements of increased gain and resolution to improve remote sensing, space based radar, satellite communications, and space science missions. The hoop column antenna is one space-frame concept being studied at LaRC to satisfy this technology need.

In order to include experimental testing as part of the technology development program, a 15-meter diameter hoop column antenna (Fig. 1) has been built and initial structural and electromagnetic tests completed. Structural tests were conducted at the Harris corporation where the antenna was built and at Langley Research Center. Electromagnetic tests were conducted in the Near-Field Test Laboratory (NFTL) at Martin Marietta Aerospace (MMA) in 1985. Details of these results and antenna design specifics are given in several references (Hoover, 1986; Anon., 1986; Campbell, 1988; Belvin, 1987).

The antenna structure is stiffened by cables from the column ends to the hoop (Fig. 1). Both the hoop and the column are composed of laminated graphite epoxy material. The lower chords are made of graphite, while the upper chords are quartz for good RF transparency. Control cords (96) on the backside of the reflector provide limited shape control of the RF reflective mesh surface. The shape of the reflecting surface is such that each reflector quadrant is a separate paraboloid segment with the associated vertex and focal point offset about 20 inches from the axis of the column.

After completion of the initial electromagnetic and structural dynamic tests, a 4-year technology development effort was initiated involving Controls, Structures, and Electromagnetics Interaction (CSEI) for large space structures. This paper describes the CSEI program and some preliminary results of related analytical work.

The CSEI program objectives are to examine interdisciplinary issues important in optimizing Large Space Antenna (LSA) performance for a variety of potential users. New antenna features are being added (Fig. 2) which include motorized cord control for more accurate and rapid remote surface actuation to improve the RF performance. Cords were adjusted manually in the 1985 near-field tests. Other new features planned are the adaptive feed and the real-time antenna figure sensor for open and closed-loop control tests of the flexible structure.

PERFORMANCE IMPROVEMENT

RF performance can be optimized not only by making the reflector surface smoother (Ruze, 1966), but by electronic compensation using an adaptive feed array. The principle of this concept is shown in figure 3. If a physical distortion occurs in the reflector, as shown in the figure, a proportional phase distortion will occur in the aperture plane degrading the far-field pattern shape and boresite gain. Partial compensation for the distorted phase front can be realized using a feed array with adjustable phase and amplitude distribution. This type of performance correction should be possible for both rapid and slowly changing antenna shape in the CSEI program.

Computer simulations representing a multi-element feed array with the 15-meter reflector and the actual 61 mils RMS surface distortions show both boresite gain and sidelobe level improvement at C-band (figs. 4,5). Figure 4 also shows how smooth the surface must be in order to have a performance improvement equivalent to the adaptive feed. Radiation pattern improvement near the main beam is indicated in figure 5 compared to the one feed element case. As can be seen, the main beam shape is essentially restored to the perfectly smooth case when the 37-element feed is used to compensate for the surface distortion. Other studies are underway to evaluate the adaptive feed compensation at higher frequencies and rougher surfaces as might occur in space.

CONCLUDING REMARKS

Fabrication and assembly of the surface adjustment system is near completion and tests are expected to begin early in the spring of 1988. The first set of tests will examine three primary areas of interest: limit of surface smoothness that can be accomplished using the precision control motors, deployment repeatability for multiple deployments, and dynamic surface vibration control using measured cord tension as input to the motorized cord controller.

Following these experiments, electromagnetic tests will be conducted in the MMA near-field facility and will involve adaptive feed tests and later include closed-loop control dynamic testing for real-time surface control. These tests will address conditions that could exist in space due to slew-and-track and slew-and-point antenna maneuvers.

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Fig. 1. 15-meter antenna in Martin Marietta Near-Field Facility

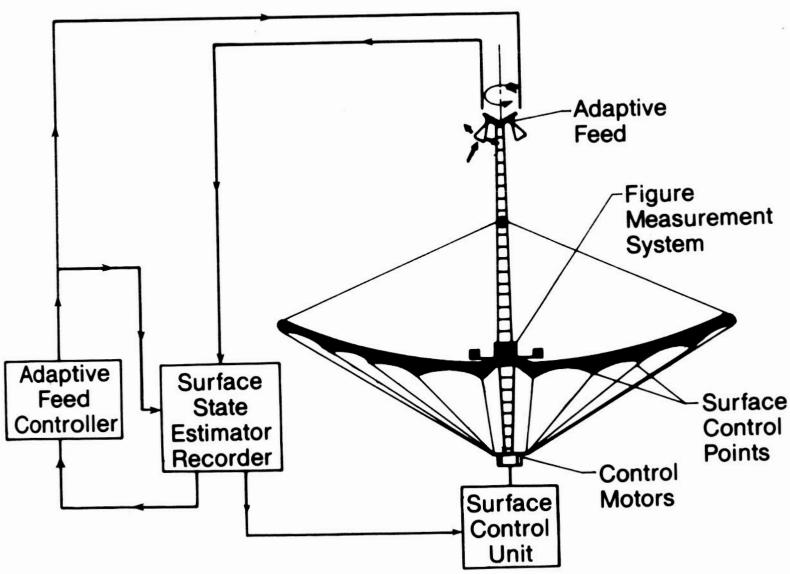

Fig. 2. 15-meter antenna geometry for the interdisciplinary research program

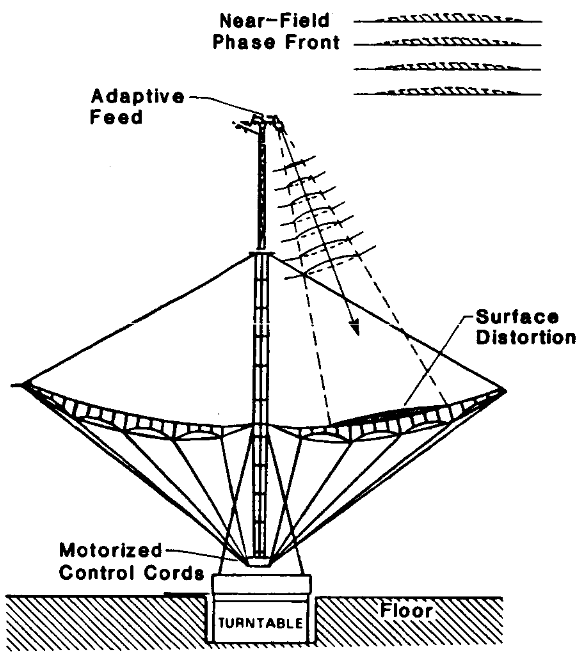

Fig. 3. Adaptive feed compensation

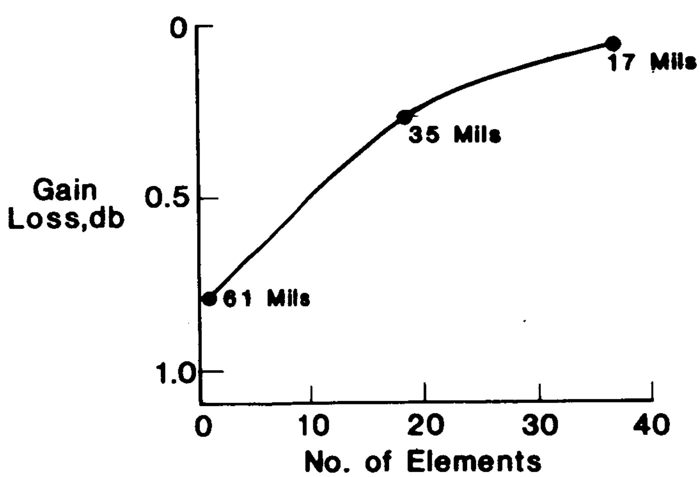

Fig. 4. Boresite gain improvement (C-band)

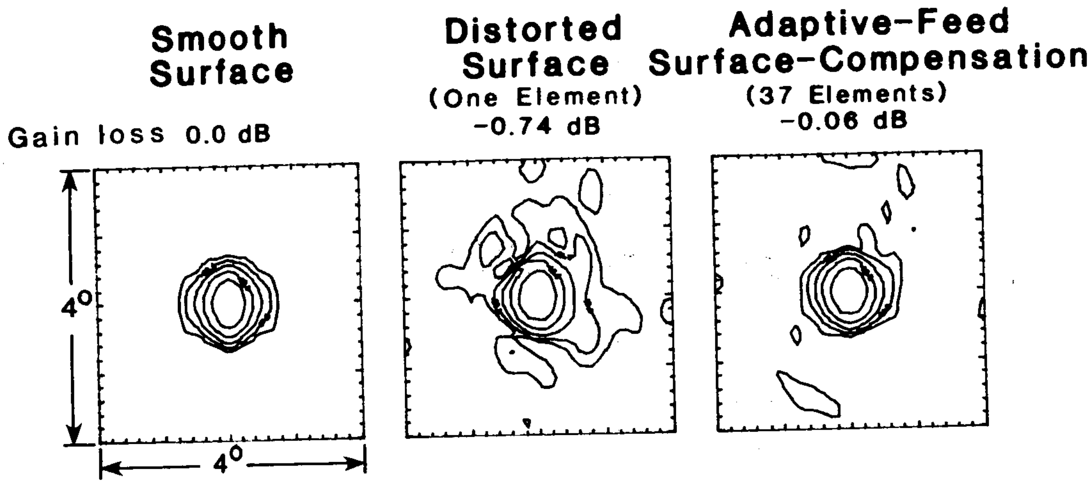

Fig. 5. Radiation patterns (C-band)